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nto two main categories:

1. *Updates to reflect the latest ops concepts, ground system configuration, etc.*
2. *Updates to reflect replacement of X-band with Ku-band.*

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Gamma-Ray Large Area Space Telescope (GLAST) Project

Mission Operations Concept Document

Revision A

August 28, 2003

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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FIGURES

ACRONYM LIST

ACD	Anticoincidence Detector
AGN	Active Galactic Nuclei
ARR	Auto-Repoint Request
ASI	Agenzia Spaziale Italiana (Italian Space Agency)
~~ASDC~~	~~ASI Science Data Center~~
ATS	Absolute Time Sequence
BAP	Burst Alert Processor
BGO	Bismuth Germanate
CCB	Configuration Change Board
CCHP	Constant Conductance Heat Pipes
CCSDS	Committee for Space Data Systems
C&DH	Command and Data Handling
CI	Calculated Information
CMD	Command
COMM	Communications Subsystem
COP-1	Communications Operations Procedure-1
COTS	Commercial Off-the-Shelf
CPU	Central Processing Unit
CRR	Candidate Re-point Recommendation
CsI	Thallium-doped Cesium Iodide
CTV	Compatibility Test Van
DAS	Demand Access System
DPU	Data Processing Unit
EGRET	Energetic Gamma Ray Experiment Telescope
EPS	Electrical Power System
E&PO	Education and Public Outreach
ETE	End-to-End test
ETR	Eastern Test Range
FDF	Flight Dynamics Facility
FITS	Flexible Image Transport System
FOT	Flight Operations Team
GBM	GLAST Burst Monitor
GCN	Gamma Ray Burst Coordinates Network
GRB	Gamma Ray Burst
GeV	Billion Electron Volts
GI	Guest Investigator
GIOC	GBM Instrument Operations Center
GLAST	Gamma-ray Large Area Space Telescope
GSSC	GLAST Science Support Center
GN	Ground Network
GN&C	Guidance, Navigation, and Control
GPS	Global Positioning System
GRB	Gamma Ray Burst
GS	Ground Station

GSFC	Goddard Space Flight Center
HEASARC	High Energy Astrophysics Science Archive Research Center
ICD	Interface Control Document
IOC	Instrument Operations Center
IPV	Internal Pressure Vessel
IRU	Inertial Reference Unit
ISI	Immediate Summary Information
ITS	Immediate Trigger Signal
kbps	Thousand Bits Per Second
km	Kilometer
L0	Level-Zero
L&EO	Launch and Early Orbit
LAN	Local Area Network
LAT	Large Area Telescope
LAT DPF	Large Area Telescope Data Processing Facility
LHEA	Laboratory for High Energy Astrophysics
LIOC	LAT Instrument Operations Center
MA	Multiple Access
MAR	Multiple Access Return
Mbyte	Million Bytes
MeV	Million electron Volts
MOC	Mission Operations Center
MSFC	Marshall Space Flight Center
NaI	Sodium Iodide
NASA	National Aeronautics and Space Administration
NCC	Network Control Center
NiH2	Nickel Hydrogen
NORAD	North American Air Defense Command
NPG	NASA Policy and Guideline
NRA	NASA Research Announcement
PB	Playback
PI	Principal Investigator
PROCs	STOL procedures for the telemetry and command system
PROP	Propulsion Subsystem
RF	Radio Frequency
RTS	Relative Time Sequence
RS	Reed-Solomon
SA	Single Access
SAA	South Atlantic Anomaly
SCP	Stored Command Processor
SOH	State of Health
SA	S-Band Single Access
SN	Space Network
SSR	Solid State Recorder
STDN	Spacecraft Tracking and Data Network
STOL	Spacecraft Test and Operation Language

SWSI	Space Network Web Services Interface
SWG	Science Working Group
TB	10^{12} Bytes
TBD	To Be Determined
TBR	To Be Resolved
TCP/IP	Transmission Control Protocol / Internet Protocol
TCS	Thermal Control Subsystem
TDRSS	Tracking and Data Relay Satellite System
TLM	Telemetry
ToO	Target of Opportunity
TR	Trigger Record
TRIGDAT	Trigger data type
TTE	Time-tagged Event
UR	Update Record
USN	Universal Space Network
WDISC	White Sands Complex Data Interface Service Capability
WSC	White Sands Complex
ZMB	Zero Momentum Bias

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this document is to establish an operations concept for the GLAST mission. The GLAST mission involves the 5-year operation of the GLAST spacecraft and instruments to perform gamma-ray measurements over the entire celestial sphere with a sensitivity of a factor of 30 or more than obtained by earlier space missions. This document describes the flight and ground operations activities, interfaces, and overall operations flow that support the requirements for GLAST mission planning, scheduling, commanding, monitoring, and science data delivery to the GLAST Science Support Center (GSSC). It is intended as an introduction to GLAST mission operations to a range of users including science team members, sustaining engineering personnel, and management. The Mission Operations Concept Document is not a requirements document, but is to be used as a resource for the mission development cycle and a source of derived requirements. The operations concepts described here will also help guide the development of the GLAST Mission Operations Center (MOC) and interfaces to other elements of the GLAST Ground Segment.

1.2 SCOPE

The scope of this document includes all operations-related plans for the implementation of the GLAST mission, specifically including the following:

- Overviews of the science, spacecraft, instruments, and ground segment operations
- Flight operations activities including mission planning, commanding, monitoring, flight dynamics support, Gamma Ray Burst (GRB) detection and notification, Targets of Opportunity (ToO) support, and sustaining engineering
- Operations organization, assigned responsibilities, and management

1.3 APPLICABLE DOCUMENTS

The following documents were referenced during the development of this document. The reader should refer to the most current versions of these documents for further information. Most of the documents are available on the GLAST Project web sites at http://glast.gsfc.nasa.gov/.

- “GLAST Science Requirements Document”, 433-SRD-0001
- “GLAST Mission System Specification Document”, 433-SPEC-0001
- “GLAST Spacecraft Performance Specification”, 433-SPEC-0003.
- “GLAST Gamma–ray Burst Monitor (GBM) Instrument – Spacecraft Interface Requirements Document”, 433-IRD-002

- “GLAST Large Area Telescope (LAT) Instrument – Spacecraft Interface Requirements Document”, 433-IRD-002
- “GLAST Project Data Management Plan”, 433-PLAN-0009
- “GLAST Science Support Center Functional Requirements Document”, 433-RQMT-002
- “GLAST LAT-GBM ICD”, 433-ICD-0001
- “GLAST Ground System Requirements Document”, 433-RQMT-0006

2.0 MISSION OVERVIEW

GLAST scientific objectives will be satisfied by two instruments. The main instrument, the Large Area Telescope (LAT), will have superior effective area, angular resolution, field of view, and dead time that together with the GLAST Burst Monitor (GBM) will provide a factor of 30 or more advance in sensitivity, as well as provide capability for study of transient phenomena. The GBM will have a field of view several times larger than the LAT and will provide spectral coverage of gamma-ray bursts that extends from the lower limit of the LAT down to 10 keV. With the LAT and GBM, GLAST will be a flexible observatory for investigating the great range of astrophysical phenomena best studied in high-energy gamma rays.

Spectrum Astro is responsible for the design and manufacture of the spacecraft, integration of the scientific instruments with the spacecraft to form the observatory, integration of the complete space vehicle/observatory with the Delta launch vehicle, and launch and early orbit activities. NASA/GSFC has program management and end-to-end mission systems engineering responsibility. GLAST is an international collaboration of government agencies and academic institutions from the United States, France, Germany, Japan, Italy, and Sweden. The LAT is a joint project with NASA and the U.S. Department of Energy. The LAT will be constructed by Stanford University, the Stanford Linear Accelerator Center, the University of California, Santa Cruz, the Naval Research Laboratory, NASA Goddard Space Flight Center, and the international partners. The GBM is a joint project with Marshall Space Flight Center, the University of Alabama, and the Max-Planck Institute in Germany. The Tracking and Data Relay Satellite System (TDRSS) is scheduled to provide the primary command and data acquisition services throughout the mission.~~The Italian Space Agency (ASI) is contributing the Malindi ground station in Kenya for spacecraft telemetry downlink and command uplink.~~ Universal Space Network of Horsham, PA is ~~also scheduled to~~ supporting GLAST using their South Point, Hawaii and Dongara, Australia ground stations as ~~a primary~~ backup sites for spacecraft telemetry downlink and command uplink. The Wallops Ground Station located on Wallops Island, VA is also supporting GLAST as a backup site for spacecraft telemetry downlink and command uplink.

The GLAST spacecraft will be launched on a Boeing Delta II 2920H-10 vehicle from the Eastern Test Range (ETR), Florida. A launch date of September 2006 is currently scheduled. GLAST will be inserted into an orbit at an altitude of 565 km and an inclination of 28.5 degrees, orbiting the Earth once every 96 minutes. Following a 60-day checkout period, the nominal 5-year science mission will commence.

2.1 GLAST SCIENCE OVERVIEW

The high-energy gamma-ray universe is diverse and dynamic. Measuring the various characteristics of the many types of gamma-ray sources on timescales from milliseconds to years places demands on the GLAST mission. GLAST has the following specific scientific objectives:

1. Identify and study nature's high-energy particle accelerators through observations of active galactic nuclei, GRBs, pulsars, stellar-mass black holes, supernova remnants, Solar and stellar flares, and the diffuse galactic and extragalactic high-energy background.
2. Use these sources to probe important physical parameters of the Galaxy and the Universe that are not readily measured with other observations, such as the intensity and distribution of intergalactic infrared radiation fields, magnetic field strengths in cosmic particle accelerators, diffuse gamma-ray fluxes from the Milky Way and nearby galaxies, and the diffuse extragalactic gamma-ray background radiation.
3. Use high-energy gamma rays to search for a variety of as yet undetected and/or new phenomena, such as particle dark matter and evaporating black holes.

Because of its unique capabilities and the great increment in sensitivity it offers in a largely unexplored region of the electromagnetic spectrum, GLAST draws the interest of several scientific communities. The international high-energy astrophysics and high-energy particle physics communities together have been particularly active in developing the mission and the necessary technologies.

2.2 GLAST OBSERVATORY OVERVIEW

2.2.1 Spacecraft Overview

The GLAST observatory comprises two major instruments and the spacecraft bus. Figure 2-1 locates the two instruments and defines the principal axes. The GLAST spacecraft provides the required structural, thermal, electrical, attitude control, propulsion, and data/communications. Descriptions presented here do not represent the project requirements. Requirements are available in the documentation listed in Section 1.3.

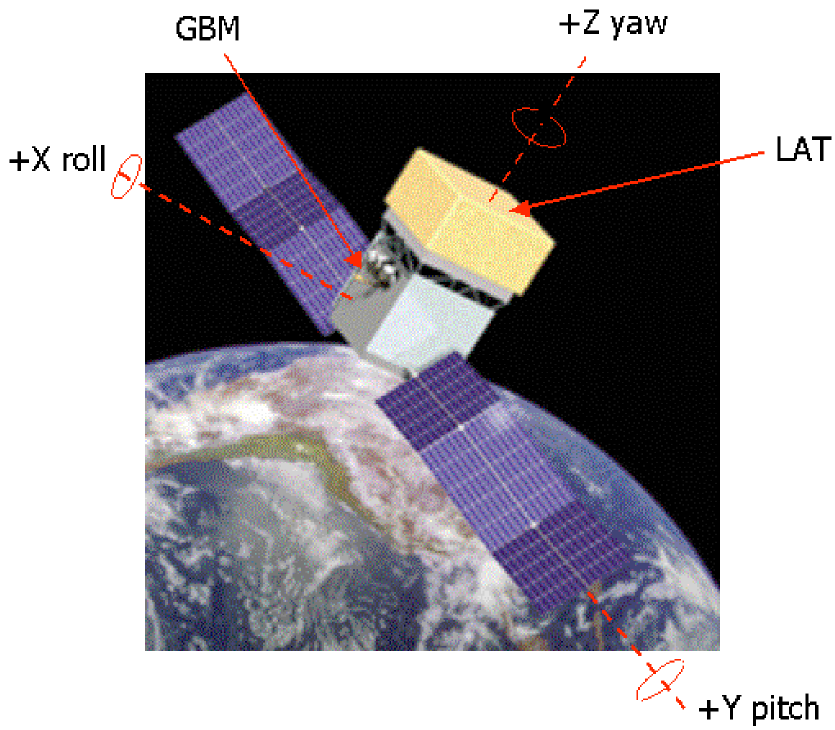

Figure 2-1: Instrument Locations and Principal Axes

The spacecraft bus functional components are briefly described in terms of their major functionality.

2.2.1.1 Command and Data Handling (C&DH) Subsystem

The GLAST Command and Data Handling (C&DH) subsystem provides several major functions: receipt, storage, and distribution of commands, telemetry and data; storage and execution of software; transfer of data to and from spacecraft bus components and instruments; distribution of time, frequency, and navigational information. Software commands are processed through the C&DH for every subsystem before being transferred to the appropriate subsystem/instrument. Hardware commands are immediately executed. Standard interfaces to all instruments and bus components for commands are used to ensure uniformity and integrity. The spacecraft is always configured to receive commands. A RAD750 processor (CPU) performs all spacecraft processing, including command, telemetry, and attitude control, as well as managing the interface for the instruments.

The C&DH accepts data at the uplink rates specified in the Mission System Specification from either TDRSS Space Network (SN) or the Ground Network (GN) links. The GN consists of ground stations such as the Malindi, Kenya Ground Station provided by the Italian Space Agency (ASI), ~~and~~ the Universal

Space Network commercial sites, and the Wallops Ground Station. The C&DH validates commands according to the CCSDS COP-1 standard for commands. Once commands are received and validated by the C&DH, they are either distributed immediately or stored for later execution. Real-time commands are distributed to the appropriate subsystem immediately after receipt and validation. Absolute time and relative time commands are recognized by the C&DH and stored for later execution. Both absolute time command loads and relative time command sequences can contain interleaved spacecraft bus and instrument commands.

The C&DH uses standard protocols for the transfer of housekeeping, science, and other data. It receives housekeeping data, science data, and other information from the instruments and housekeeping data from the spacecraft bus components. All of the data is stored on-board for later transmission to the ground. The C&DH provides lower downlink rates for real-time data for use during safe mode or when communications links cannot support the housekeeping data downlink rate.

The C&DH stores all data on-board for playback to the ground during the daily ~~5-7 GN~~ 4-5 SN communications contacts. The Solid State Recorder (SSR) has cross strapped interfaces for the power supplies. The 96 Gbit capacity of the recorder has sufficient storage for 36 hours of the average science data rates of 300 kbps and 25.5 kbps of the LAT and GBM respectively. The SSR is divided into multiple addressable segments or partitions to simplify storage of data by type and downlink priority. The science data from both LAT and GBM will be stored in the science partition and then downlinked to the ground~~using the X-band antenna~~. The spacecraft housekeeping data will be stored in the housekeeping partition and also~~then~~ downlinked to~~using~~ the ground~~S-band antenna~~. Nominally, the data within each partition is played back in the order it was recorded: that is, first in, first out. However, in the event the most recently recorded data needs to be downlinked first, the C&DH can begin the playback anywhere within the recorded data via ground commands. Playback will proceed from the specified starting location to the most recent data recorded.

The C&DH also provides the computing resources to control the spacecraft and manage the instrument interfaces during launch, activation, nominal operations, and safe mode. It can accept changes to its flight software generated on the ground.

The C&DH receives the GPS Derived Time from the Guidance, Navigation, and Control (GN&C) and then it is routed to all other spacecraft functions.

2.2.1.2 Telecommunications (COMM) Subsystem

The telecommunications (COMM) subsystem is compliant for communications with the GN and Tracking and Data Relay Satellite System (TDRSS) for exchange of commands and data. The design features both an S-Band and Ku~~X~~-Band downlink, and an S-band uplink. The S-band downlink is used for rapid burst alert notifications, spacecraft alert messages, and housekeeping telemetry playback. The S-band uplink is used for commanding during either space or ground network contacts.~~ground station supports or rapid turnaround commanding using the space network.~~ The Ku-band is capable of downlinking the burst alerts notifications (if in a SN contact), stored housekeeping, and stored science data through the TDRSS link.~~The X-band downlink is used solely for the stored science data downlink.~~ The S-band downlink to the ground network will be utilized as a backup to the Ku-band downlink for the stored housekeeping data.

Omni-directional antennas are used for transmitting data via the S-band to the GN and SN. A gimbaled ~~medium gain~~ antenna is used to transmit the data over the Ku~~X~~-band to the S~~G~~N~~ stations~~. Recorded housekeeping data and diagnostic data can also be downlinked via S-band only to the ground station.

The S-band antennas are also used to receive commands from the ground stations and TDRSS. Commanding through TDRS is done using the MA or SSA forward link service.

2.2.1.3 Electrical and Power Subsystem (EPS)

The Electrical and Power System (EPS) provides power to the spacecraft bus components and instruments. Under nominal conditions, EPS operates autonomously, performing battery discharging/charging, and power distribution. A pair of single-axis gimbaled solar arrays generates approximately 3090 watts (@ 5 years) of electrical power during the daylight part of the orbit. Excess power is distributed to the 125 A-hour NiH2 IPV batteries for recharging. Battery charging rates are selectable by ground command or may be controlled by on-board software. Charging rates may change due to battery performance or available solar array power throughout the mission life. Higher rates may be used early in the mission, after the solar arrays have been deployed and during any off-nominal attitudes that result in decreased power output. Charge rates are expected to change infrequently. Upon exiting orbit night, the batteries will begin recharging and enter trickle charge according to the selected voltage/temperature setting. In the event of a survival mode entry due to power problems or other faults, non-essential bus loads will be taken offline with sufficient warning to the instruments to allow them to gracefully shut down.

2.2.1.4 Guidance Navigation and Control (GN&C) Subsystem

GLAST Guidance Navigation and Control (GN&C) comprises the functionality of attitude determination and control. Attitude operations are required during all mission phases. The GN&C function provides for the spacecraft attitude control, orbit determination, and appendage articulation including both solar array tracking and gimbaled antenna pointing (~~X~~Ku-Band).

The attitude control function autonomously provides attitude determination through use of star trackers and inertial reference unit (IRU) data. The spacecraft establishes and maintains spacecraft attitude and provides the actuator commands for spacecraft three-axis attitude control. Attitude control, including stable pointing and slewing, is accomplished with four reaction wheels in a zero-momentum bias (ZMB) configuration. Wheel momentum is unloaded by three orthogonal magnetic torquer rods, using a 3-axis magnetometer for field sensing. Star tracker and IRU data will typically be used in the high precision or fine pointing modes for science. Backup sensors (such as Sun Sensors and magnetometers) are used for attitude determination in contingency or other non-optimal pointing performance modes. Attitude data are output to the C&DH for inclusion into the spacecraft housekeeping data.

Limits on pointing angles and maneuver durations such as Sun, Earth limb, Moon, and South Atlantic Anomaly (SAA) will be derived from instrument thermal and pointing constraints.

The GPS Navigational Signal will be used for primary orbit (position and velocity) and time determination. The ephemeris data is provided to the C&DH for inclusion into the housekeeping data. Based on the GPS Navigational Signal, the GPS derived time for the GLAST satellite is determined and sent to the C&DH.

The GN&C function will use space ~~and ground~~ network~~station~~ information (Geographic position, altitude, etc.) stored on-board the spacecraft and GLAST position information to determine the correct pointing of the Ku~~X~~-Band gimbaled antenna~~s~~. In this scenario the MOC will provide as part of the daily loads (either as a stored command or as a separate load) the TDRS satellite~~ground station~~ that is to be tracked for each ~~orbit~~support. Prior to the specified TDRS~~ground station~~ coming into view, the GN&C will command the antenna~~(s)~~ to a position such that the antenna will be pointing at the TDRS satellite~~ground station~~ as it enters GLAST view. The GN&C would then provide needed commanding to the Ku~~X~~-band antenna to track the TDRS satellite~~ground station~~ as it passes through view.

GN&C will also calculate updates to the solar array angles to track the sun. Solar array tracking can either use sun and GLAST position to determine the correct solar array position or use a commanded constant rate. The spacecraft can be commanded to apply a bias to the solar array position in the event it becomes necessary to offset the solar array from the sun.

2.2.1.5 Structure and Mechanisms

The GLAST Structures and Mechanism Subsystem is made up of the spacecraft primary and secondary structures. These provide support for both the instruments and attached mechanisms such as the Ku~~X~~-band ~~deployable~~ antenna, star tracker optical bench, and deployable gimbaled solar arrays. The spacecraft structure is further divided into primary and secondary structures. The primary structure will carry the fundamental launch loads and is made up of two ring sections separated by vertical longeron tubes and covered by honeycomb shear panels. Flexures attached to the primary structure support the heavy (2700kg) LAT instrument. The secondary structure, which does not carry fundamental launch loads, provides the mounting points for the optical bench, GBM instrument array, S-band antennas, and the propulsion frame.

2.2.1.6 Thermal Control Subsystem (TCS)

The GLAST Thermal Control Subsystem (TCS) design is a cold-biased system employing passive thermal control augmented by the selective use of thermostatically controlled heaters. Thermal control is provided chiefly through the use of multi-layer insulation, two-phase heat transfer devices, Constant Conductance Heat Pipes (CCHP), heat straps, surface finishes and coatings, and radiating surfaces. Heaters are used to minimize the impact of eclipse periods on component temperatures. Heat flow is minimized between the spacecraft bus and instrument using low thermal conductivity flexures.

2.2.1.7 Propulsion (PROP) Subsystem

The GLAST Propulsion (PROP) System provides the thrust necessary to de-orbit the mission. The Hydrazine blow-down propulsion module consisting of a propellant tank and 12 thrusters will be employed after the nominal mission ends to dispose of GLAST in a controlled manner consistent with NASA guidelines for safe disposal of orbital spacecraft.

2.2.2 Overview of the Instruments

There are two instruments on the GLAST mission. The Large Area Telescope (LAT) and the GLAST Burst Monitor (GBM).

2.2.2.1 Large Area Telescope (LAT)

The LAT consists of four subsystems: a solid state detector (silicon strip) pair conversion tracker for gamma-ray detection and direction measurement, Thallium-doped Cesium Iodide (CsI) calorimeter for measurement of the energies, a plastic scintillator anticoincidence system to support rejection of signals from the intense background of charged particles, and a Data Acquisition System (DAQ) to process the incoming signals from the other three subsystems. The LAT consists of a 4 _ 4 array of identical towers, and will have approximately 880,000 silicon-strip detector channels. Together with the calorimeters the LAT will be capable of detecting and measuring transient phenomenon in the energy range of 20 MeV - 300 GeV.

2.2.2.2 GLAST Burst Monitor (GBM)

The GBM will have 12 Sodium Iodide (NaI) scintillators and two Bismuth Germanate (BGO) scintillators mounted on the sides of the spacecraft. The combined detectors will view the entire sky not occulted by Earth, with energy coverage from a few keV to 30 MeV, overlapping with the lower energy limit of the LAT and with the range of GRB detectors on previous missions.

2.2.3 Observing Strategies

During the first year of the GLAST mission, the observatory will operate primarily in Sky Survey Mode. This approach takes maximum advantage of the large fields of view of the LAT and the GBM, allowing a full sky survey on short (hourly) timescales. The GSSC will monitor the sky coverage and may request modifications to the spacecraft motion to achieve optimal scientific return. A feature of observatory motion during Sky Survey Mode is ± 60 degree rocking of the observatory with respect to the orbit plane to provide scanning of the entire celestial sphere. The rocking motion of the spacecraft is initially expected to be a stepped profile with a one orbit up and one orbit down pattern. During subsequent years guest observers will propose inertially pointed observations in Pointed Observation Mode or observations based on Sky Survey Mode. Specific targets may also include secondary targets to be observed during earth occultation of a primary target.

2.3 GLAST DATA PHILOSOPHY

The GLAST data will be distributed widely to the scientific community, regardless of the analyzers' involvement in GLAST's development. Although the instrument teams have proposed scientific investigations with the instruments they develop--indeed, the teams are responsible for large projects such as the preparation of catalogs--a large, well-funded Guest Investigator (GI) program will support and encourage analysis of GLAST data by scientists who are not affiliated with the instrument teams and are not primarily gamma-ray astrophysicists.

During the first year of scientific operations the LAT will carry out a sky survey while the instrument teams calibrate their instruments and validate the data. During this first year the routinely collected data~~ (i.e., the bulk of the data downlinked through the GN)~~ will be accessible only to the instrument teams and a small number of scientists selected through the GI program. However, data from transients (e.g., burst alert data downlinked immediately to the ground~~through the SN and data from bursts or other transients downlinked through the GN~~) will be processed rapidly and released immediately to the wider community. All data collected during this first year will become public at the end of the year.

For the remainder of the mission after the first year the data will be processed rapidly and made public as soon as possible (typically within two days after the data are collected). The instrument teams will acquire their instrument's data from their own archives, while the scientific community will extract data from the online databases at the GSSC~~ or at the Agenzia Spaziale Italiana (ASI) mirror site~~.

GLAST operations are designed to be as responsive as possible to the data needs of a large user community. Data may be analyzed soon after they are collected. GLAST will facilitate data analysis through software tools and documentation provided on the GSSC website. Burst data collected by the instruments will be distributed to the GCN ~~on timescales as short as~~within 7 seconds ~~by the GCN~~. In response to transient phenomena, the observing plan can be interrupted through ToOs on timescales as short as 6 hours or less.

The definitive statement about GLAST's data policies can be found in the GLAST Project Data Management Plan.

2.3.1 Science/User Community

The GLAST Science Team is made up of world experts in Gamma-Ray astronomy, theory, space instrumentation, multi-wavelength follow-up observations, and outreach. GLAST supports the general science community ~~and~~ in responding to Target of Opportunities and a Guest Investigator program. (see section 3.4.5 for more information).

2.4 GROUND SYSTEM ARCHITECTURE OVERVIEW

The GLAST Ground System provides for:

- Radio Frequency (RF) communications with the spacecraft
- Spacecraft & instrument monitoring and control
- Mission Planning
- GRB alert notification
- Science data processing
- Science data archive and distribution

These functions are performed by existing and new facilities. A GLAST Ground System mission architecture overview is shown in Figure 2-4.

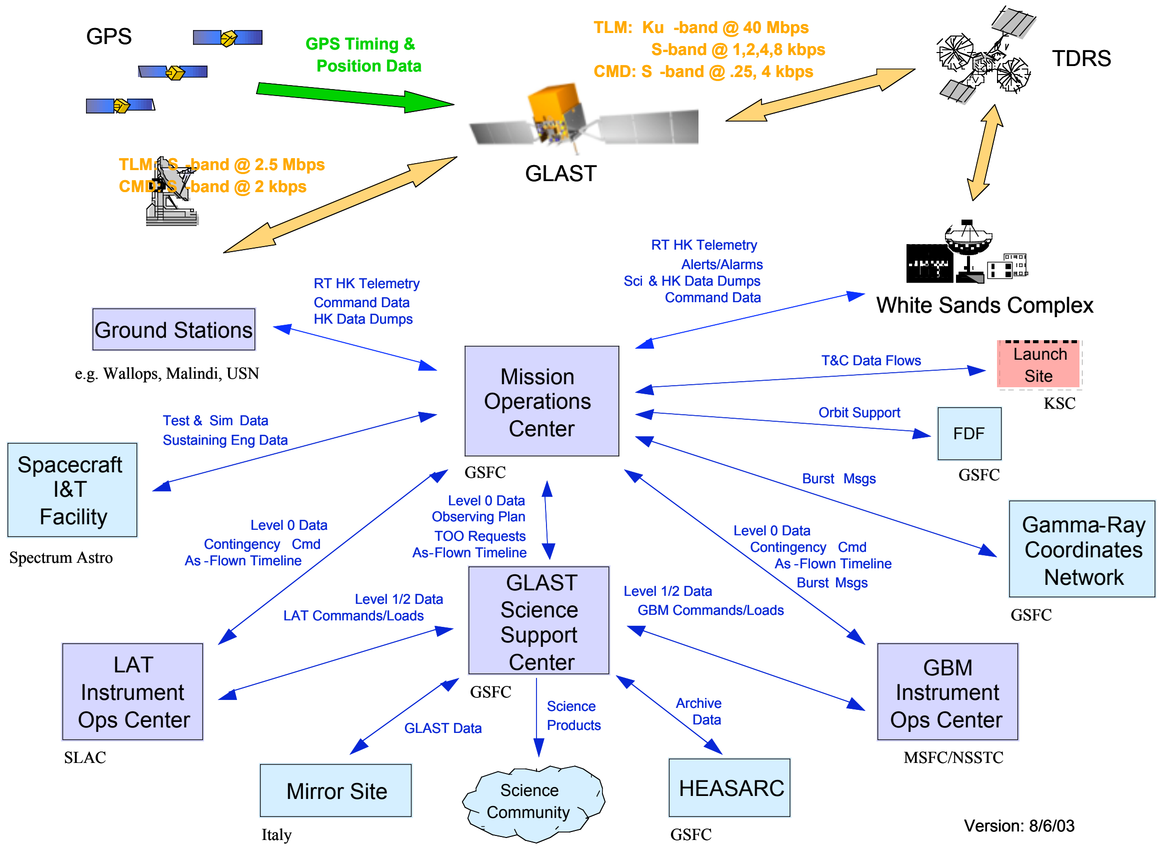

Figure 2-4: GLAST Mission Architecture

2.4.1 ~~Malindi~~ Ground Stations

The ground stations will provide launch, early orbit and contingency support for S-band telemetry and command communications. The potential stations include (1) the Malindi ground station in Kenya, Africa, (2) the Universal Space Network commercial stations in South Point, Hawaii and Dongara, Australia, and (3) the Wallops Ground Station in Wallops Island, VA. ~~provides space-to-ground RF communications with the GLAST spacecraft.~~ These stations support~~s~~ simultaneous S-band data acquisition at 2.5 Mbps and S-band command (CMD) functions at 2 kbps. ~~The station also supports the X-band science data downlink at 20 Mbps.~~ The ground stations uplink~~s~~ spacecraft commands received from the MOC, and provide~~s~~ real-time S-band telemetry and pass statistics to the MOC during each pass. The ground station provides playback of recorded Housekeeping~~S-band and X-band~~ telemetry files to the MOC post-pass. ~~The command and telemetry data are transferred over the Italian Space Agency Network (ASINet) link between the MOC and the Malindi station. ASI provides Malindi station operations, including the transmission of telemetry to and receipt of commands from the spacecraft. There will be three to five Malindi passes per day scheduled by the MOC to support mission communication requirements during nominal on-orbit operations.~~

~~*2.4.2 Universal Space Network (USN) Ground Station*~~

~~The Universal Space Network (USN) provides space-to-ground RF communications with the GLAST spacecraft from its Hawaii site. The stations support simultaneous S-band data acquisition at 2.5 Mbps and S-band command functions at 2 kbps. The stations also support the X-band science data downlink at 20 Mbps. The ground stations uplink spacecraft Commands received from the MOC, and provide real-time S-band telemetry and pass statistics to the MOC during each pass. The ground stations provide playback of recorded S-band and X-band telemetry files to the MOC post-pass. The command and telemetry data are transferred between the MOC and the USN network control center located in Horsham, PA. There will be three to five USN passes per day scheduled by the MOC to support mission communication requirements during nominal on-orbit operations.~~

2.4.2~~3~~ Tracking and Data Relay Satellite System (TDRSS)

2.4.2~~3~~.1 TDRSS Demand Access System (DAS)

The DAS uses the S-Band Multiple Access Return (MAR) capabilities of TDRSS. This system provides near continuous on demand S-band coverage for the downlink of spacecraft alerts with rapid delivery to the ground. Low rate State of Health (SOH) data can also be provided through the DAS to support contingency operations and Launch and Early Orbit (L&EO). The GLAST spacecraft can determine autonomously when to transmit data via DAS. The DAS will communicate schedule and status information to and from the MOC via the Space Network (SN) Web Services Interface (SWSI). Use of this TDRSS service is scheduled using the SWSI to communicate via the Network Control Center (NCC) at NASA/GSFC. The MOC obtains TDRS handover schedules from SWSI for subsequent uplink to the spacecraft.

2.4.2~~3~~.2 TDRSS White Sands Complex Data Interface Service Capability (WDISC)

WDISC provides TDRSS Multiple Access (MA) and ~~S-Band~~ Single Access (SA) forward and return S-band services. These services are scheduled via SWSI on a request basis. The S-band forward service will provide the primary mechanism for commanding the spacecraft. The S-band return service will be used in contingency situations if problems are encountered with the Ku-band return service.~~TDRSS MA services include forward and return telecommunications services, and tracking services. The WDISC forward service allows for quick response commanding for Targets of Opportunity (ToO) and anomaly response, and for L&EO support.~~

2.4.2.3 TDRSS Ku-Band Return Service

The SN provides a Ku-band return service for high rate return link communications with the spacecraft. This will be used as the primary mechanism for downlinking real-time Housekeeping data, recorded Housekeeping data, and recorded Science data. The real-time data can also include alert, alarm, and diagnostic telemetry. Approximately 4-5 SN contacts will be scheduled daily to support the GLAST data downlink requirements.

2.4.3~~4~~ Ground Communications Network

The GLAST ground communications network provides data transport between the MOC at NASA/GSFC and several ground network interfaces. The MOC will interface with systems such as the GSSC at Goddard, the White Sands Complex (WSC) in NM, the Network Control Center (NCC) at NASA/GSFC, the Wallops~~USN~~ ground station ~~hub~~ in Wallops Island, VA~~Horsham, PA~~, the spacecraft vendor facility (Spectrum Astro) in Gilbert, AZ, the LAT IOC in Palo Alto, CA, and the GBM IOC in Huntsville, AL.

2.4.4~~5~~ GLAST Mission Operations Center (MOC)

The MOC, located at NASA/GSFC, will operate the GLAST satellite and instruments. The MOC will support pre-launch operations, launch, 60-day checkout, normal and contingency operations.

The MOC performs all spacecraft commanding, telemetry monitoring, and Level-0 data processing and delivery to the GSSC, LAT Instrument Operations Center (LIOC), and GBM Instrument Operations Center (GIOC). Level-0 processing of the data will be done on files received post-pass from the ground stations. The MOC incorporates automation of spacecraft operations and data processing to permit a small operations team. Archive of all raw data for the mission is provided off-line with rapid retrieval of the last 7 days. A 30-day on-line archive of housekeeping telemetry, command transmissions, and MOC processing statistics and status is also maintained.

2.4.5~~6~~ GLAST Science Support Center (GSSC)

Located at the Laboratory for High Energy Astrophysics (LHEA) at GSFC, the GSSC is the interface between the GLAST mission and the scientific community. Thus the GSSC will provide GLAST data, analysis software and documentation to users, and will support the Guest Investigator (GI) program through developing the NASA Research Announcement, organizing the peer-review process, and assisting investigators analyze data.

The GSSC will ingest the Level-1 data from the IOCs, store them in its online databases, and transfer these data to the HEASARC as the permanent mission archive. The GSSC will also maintain the science timeline, which will be based on accepted GI proposals and the requests of the IOCs. Because of the potential impact on the science timeline, commands from the IOCs to their instruments will pass through the GSSC.

The GSSC will support the Project Scientist by evaluating ToO requests, and generating the order should the Project Scientist declare a ToO.

The GSSC combines the functions often performed by a Science Operations Center, which carries out high-level data processing, archiving and mission planning, and a Guest Observer Facility, which supports GIs. The GSSC will not support a dedicated facility to which investigators come to obtain and analyze data.

2.4.6~~7~~ LAT Instrument Operations Center (LIOC)

The LIOC is located at the Stanford Linear Accelerator Center in Palo Alto, CA. The responsibilities of the LIOC include data verification, LAT health and safety monitoring, LAT command generation, flight software validation and maintenance, and alert processing and logging.

2.4.7~~8~~ GBM Instrument Operations Center (GIOC)

The GIOC is located at the University of Alabama-Huntsville, AL. The responsibilities of the GIOC include data validation, GBM health and safety monitoring, GBM command generation, flight software validation and maintenance, and alert processing and logging. The GIOC is a collaborative effort between the National Space Science and Technology Center in the U.S. and the Max Planck Institute for Extraterrestrial Physics (MPE) in Germany.

2.4.8~~9~~ GRB Coordinates Network (GCN)

The GCN distributes location and light curve information for GRBs detected by all spacecraft capable of detecting GRBs to interested members of the science community. The rapid dissemination of GLAST alerts will enable ground observatories and operators of other spacecraft to plan correlative observations. The GCN is an existing system with sufficient capacity to support GLAST.

2.4.9~~10~~ HEASARC/Data Archival

The High Energy Astrophysics Science Archive Research Center (HEASARC) is NASA's archive for the high energy astrophysics missions in which NASA had a role. The GSSC computer system is part of the HEASARC system and the GSSC databases will reside on the HEASARC's storage media. The software tools that will be provided to the scientific community for the analysis of GLAST software are being developed in HEADas, the HEASARC's software system, which the HEASARC is committed to maintain. The HEASARC will become the permanent archive of GLAST's data, response functions, analysis software and documentation. GLAST's association with the HEASARC will guarantee the long-term accessibility of the GLAST data, and will ensure a multi-wavelength approach to the analysis of these data.

2.4.10~~1~~ Education and Public Outreach (E&PO)

GLAST has a substantial Education and Public Outreach (E&PO) Program, which reflects NASA Headquarters' commitment in this area. Seven projects are included under this program to reach millions of people of all ages to capitalize on the public excitement over GRBs. These include a major web-site development, television productions, curricular materials, and collaboration with teacher organizations to disseminate workshop materials.

2.4.11~~2~~ Spacecraft Vendor

Spectrum Astro may be retained for the duration of the GLAST mission to provide routine sustaining engineering support to the Flight Operations Team (FOT). A remote engineering workstation would allow engineers to review spacecraft status and trend data from the MOC data archive. Sustaining Engineering support would include, for example, expert systems engineering analysis, solar array degradation over time analysis, battery performance characterization, and thermal degradation analysis. The contractor submits periodic spacecraft system status reports to the MOC based on review of received housekeeping data. The contractor is also on-call to support anomaly resolution activities, as required.

As part of sustaining engineering agreement Spectrum Astro, in Gilbert, AZ, would maintain the flight software for the spacecraft. Any changes to the flight software are validated before uplinking the software for execution. A GLAST Configuration Control Board (CCB) will ensure that all changes are proper and that earlier versions of the software are available if anomalies are identified in subsequent versions. A flight software test bed (GLAST Hotbench) may be used to validate planned updates to the spacecraft flight software.

3.0 MISSION OPERATIONS

GLAST mission operations encompass all activities from operations concept development through the termination of on-orbit operations and science data collection. Mission operations during the normal operations phase are the responsibility of the GLAST Ground Segment. The GLAST Ground Segment has responsibility for development of the GLAST MOC, implementation of the RF communications for normal and backup operations, elements of the ground network for supporting MOC functions, and training and implementation of the FOT for GLAST operations. Spectrum Astro is responsible for spacecraft launch processing and initial 60-day post-launch checkout.

The GLAST MOC is to be developed and configured at NASA/GSFC in readiness for pre-launch operations, launch and 60-day checkout and normal operations. During the normal operations phase the MOC will be staffed by ground segment engineers (the FOT). A 5-day single-shift staffing plan is envisioned along with proven automation features in the ground system.

3.1 MISSION OPERATIONS PREPARATION

The GLAST mission requires each segment of the mission to be attentive to efficiency and cost effectiveness. The Ground Segment has been involved from the proposal stage to ensure that efficient mission operations capability is designed into all systems from the beginning. The ground system is designed for speed and flexibility both in distributing burst alerts and data and in receiving scientific input for mission planning. The automation of spacecraft operations and data processing is being implemented to allow for a small FOT and “lights-out” operations during non-staffed periods.

Mission operations preparation includes the definition of spacecraft and instrument operations requirements, coordination with external support organizations to define operational interfaces, and the development of operations plans, procedures, and other documentation. Mission operations preparation also includes simulations and training for the GLAST team.

3.1.1 Requirements Analysis and Documentation

The GLAST Ground Segment coordinates with the spacecraft and instrument teams to fully define operational requirements of the spacecraft bus and instruments. Coordination with the GLAST Science Team defines science operations requirements, goals and constraints. This information is included in documentation prepared to clearly define all operating requirements, limits and capabilities. It further provides a basis for generating spacecraft and instrument operations procedures for use by the FOT.

GLAST operations include not only the operation of the spacecraft and instruments, but also the operation of the ground system itself. Operational interfaces with external organizations (e.g.; commercial RF ground stations) are defined and documented during the pre-launch phase along with internal system operating requirements. These requirements are captured in the "GLAST Ground System Requirements Document". MOC routine and contingency operations procedures are developed based on all requirements.

3.1.2 Training

Training starts with the development of a comprehensive training plan. The primary method of training will be spacecraft and instrument systems training, documentation review, hands-on console training, simulations, and a formal evaluation and certification process. The GLAST Training Plan includes instrument and spacecraft systems training by the instrument teams and spacecraft contractor, general satellite operations training, and mission-specific procedures training for GLAST operations. MOC ground segment training includes hardware and software overviews and hands-on practice. Additional training on spacecraft and instrument operational requirements is obtained through participation in Observatory I&T activities.

Pre-launch simulations are used to train, exercise, and evaluate the GLAST team in nominal and contingency situations in all mission phases: launch, early orbit, science data collection, and maintenance functions. Pre-launch simulations include End-to-End (ETE) operations with the ground stations and spacecraft at the Spectrum Astro I&T facility, as well as internal data flows at the MOC. Post-launch, training of new FOT operators will include on-the-job-training mentoring by experienced personnel.

3.2 PRE-LAUNCH OPERATIONS

Pre-launch Operations for GLAST is defined as any pre-launch activities that include the use of the GLAST MOC as an operational entity prior to the actual launch countdown. Ground system and operations readiness will be determined by a series of ground system tests and operations simulations. The test program and schedule will be documented in the "GLAST Ground System Test Plan". Procedures for spacecraft and ground system testing will be developed to allow maximum reuse for on-orbit L&EO and normal operations phases.

3.2.1 Element Acceptance Testing

A structured, incremental approach is used for ground system testing, verification and readiness. This includes a modular build strategy for ground system development, where each build or module is integrated and tested. Build or module testability is determined during design and code walkthroughs. Module testing confirms satisfaction of design requirements. A system acceptance test plan ensures quality assurance by placing emphasis on the integrity of the delivered modules and the associated user documentation, and adherence to standards. Acceptance testing ensures the readiness of the operational system.

3.2.2 Observatory Integration and Testing

At approximately launch-14 months, a MOC system is configured at the Spectrum Astro facility to support Observatory level Integration and Test. The FOT will participate alongside the spacecraft and instrument teams to support development and validation of procedures, PROCs (STOL procedures for the telemetry and command system), command and telemetry database, and testing with the hot-bench and spacecraft. The main goal in supporting this testing is to allow the FOT access to actual telemetry and become familiar with both the spacecraft and instruments which reduces risk for later ground system testing and operations.

3.2.3 RF Compatibility Testing

RF Compatibility tests will verify the compatibility between the spacecraft and the ground communications systems (TDRSS and~~,~~ ~~Malindi and commercial~~ ground stations). All RF testing will be conducted when the spacecraft is in the Observatory I&T facility at Spectrum Astro. The ground stations will provide portable RF test equipment to interface with the spacecraft and the MOC if their interfaces cannot be verified via the Compatibility Test Van (CTV). The TDRSS RF Compatibility testing will utilize the ~~Simulations Operations Center at GSFC, the Compatibility Test Van (~~CTV~~)~~ to validate all~~communicate with a~~ TDRSS communications services used by GLAST (i.e., Ku, SA and MA services).~~, the DAS at WSC, and forward data to the MOC at GSFC.~~

3.2.4 Observatory Interface Testing

Observatory Interface Testing will verify compatibility between the observatory (spacecraft and instruments) and the MOC system. Testing will include real-time telemetry and commands, loads, data and memory dumps, and Burst Alert messages. Spacecraft Interface Testing will initially receive telemetry in a “listen-only” mode from the spacecraft during observatory I&T at the Spectrum Astro facility. The Spectrum Astro Hot Bench simulator will be utilized to ensure that all obvious interface problems are found and resolved prior to the use of the spacecraft.

3.2.5 Ground~~Mission~~ Readiness Testing

Ground~~Mission~~ Readiness Tests will verify that all ground systems, interfaces, and operations elements meet the mission requirements. These integrated system verification tests are conducted prior to the ETE tests and mission simulations. During this test phase, certain tests may be repeated as needed to maintain readiness.

3.2.6 End-to-End (ETE) Testing

ETE tests involving all ground system elements verify a proper data flow configuration between the spacecraft and the MOC. The elements include the spacecraft at the Spectrum Astro facility, ground station RF equipment, the SN, the MOC at NASA/GSFC, the GSSC, and the two IOCs. Instrument timelines and commands will be sent from the IOCs to the GSSC. The GSSC will then integrate the two IOC timelines and commands into an integrated science timeline for the MOC. Commands are sent from the MOC through the RF equipment to the spacecraft. Similarly, telemetry is sent from the spacecraft through the RF equipment to the MOC. Burst alert processing is verified through both the SN and GN interfaces. Finally, the MOC transfers Level-0 science data to the GSSC and IOCs. All practical operational data flows and processing steps are exercised and verified. An additional ETE test is planned while the spacecraft is being prepared at the launch facility in Cape Canaveral, FL.

Further ground system readiness tests are performed between the MOC and ground stations to verify proper configurations between the ground stations and the MOC. To test a ground station to MOC interface, recorded data is played back from the ground station to the MOC. MOC commands are sent to the ground station, and recorded for subsequent verification.

3.2.7 Mission Simulations

Mission Simulations will be designed to emulate the operations environment of different mission phases, including L&EO, nominal science collection, and spacecraft maintenance activities. The focus of mission simulations will be the continued training of the GLAST team, procedure validation, database verification, and system testing in the actual operations environment. There are plans for three Mission Simulations tests for L&EO, normal, and contingency operations. L&EO simulations are basically rehearsals of the L&EO timeline that exercise the launch scripts. Normal operations simulations generally rehearse a typical day-in-the-life once the spacecraft has been declared operational. Contingency simulations are rehearsals of various anomaly situations that may occur on-orbit. The MOC flight operations team~~Omitron~~ will provide lead support in planning, documenting, and conducting all operations simulations needed prior to launch. This support will be provided primarily by the Mission Operations Readiness Lead. NASA will ensure that the collection of simulation activities prior to launch demonstrates the overall readiness of the operations staff, products, and processes.

3.3 LAUNCH AND EARLY ORBIT CHECKOUT

The early orbit checkout phase begins at launch and is scheduled to complete in the first 60 days of the mission. Spectrum Astro conducts the launch and 60-day checkout from the NASA/GSFC MOC. The L&EO Director will be provided by Spectrum Astro and will generally be the lead in all aspects of mission operations during the L&EO phase. The FOT supports these activities by executing the command and control of the spacecraft and scheduling ground station and TDRSS support which are part of nominal operations. The LAT and GBM personnel support instrument activation and verification steps in the L&EO timeline. Coordination of activities and resolution of conflicts will be the responsibility of the L&EO Director.

There is no telemetry or command capability from liftoff until the first contact with the spacecraft via TDRSS. The Spectrum Astro and MOC personnel have no insight into the spacecraft or instruments status until the first on-orbit contact. Launch control center personnel will keep the MOC informed of launch status and will provide the orbit insertion vector to the Flight Dynamics Facility at GSFC. At that time, the MOC will receive real-time data through the TDRSS link to evaluate the spacecraft initialization following separation status. The housekeeping data recorded since launch will be downlinked at the first available SN or ground station support.

During the initial ground contact, Spectrum Astro engineers and MOC personnel will checkout the following:

- Initial SOH verification
- Verify attitude orientation, current/voltage as expected
- Initial command verification
- Verify Solar Array and Antenna Boom deployments
- Download stored SOH telemetry

Operations during the early orbit mission phase will be controlled by pre-defined, certified procedures and focus on verifying spacecraft and instruments' health and proper configuration. Operations during this phase are lead by Spectrum Astro and supported by the FOT, and instrument teams. The MOC will be staffed to support the checkout of the spacecraft and the instruments for nominal functionality during the 60-day checkout. This will involve 24 hour per day operations in the weeks following launch followed by a gradual ramp down of staffing to the completion of the checkout period.

A timeline of checkout activities will be created from inputs from Spectrum Astro and the instrument teams. Spacecraft and instrument operating modes are validated, operational procedures are updated based on flight system characterization, and the trending of system data is initiated. The culmination of the checkout will be a declaration by Spectrum Astro that the spacecraft functionality and interfaces have all been validated and NASA accepts the delivery on-orbit. The declaration will be followed by a Project-level review to assess post-launch and operational performance of the spacecraft, instruments and ground segment. At the conclusion of a successful checkout, responsibility for spacecraft operations is handed over from the Spectrum Astro operations team to the NASA/GSFC. The FOT will then have responsibility for operating the spacecraft and instruments and overall mission planning, while the GSSC, LIOC, and GIOC will have responsibility for the performance of the instruments and science planning.

3.4 NORMAL OPERATIONS

Normal operations begin at the conclusion of the 60-day checkout, and encompass all activities necessary to collect and process science data and maintain the spacecraft, instruments, and ground systems on a routine basis. The normal operations phase of the mission has a goal of 10 years. The first year of the mission after checkout will be devoted to completing a full sky survey of Gamma-Ray sources. The remainder of the mission will consist of supporting pointed observations for particular researchers. Several pointed observations will be supported per orbit in this phase of the mission.

It is expected that the majority of GLAST's observing time will be spent in the survey mode. The pre-planned mission timeline will be revised during the five-day work week in response to new bursts and ToOs. The frequency of the ToOs is expected to be once per month. The pre-planned observations will be stored and managed by the spacecraft Absolute Time Sequence (ATS) processor and will provide a means of performing multiple observations without the need for ground commands.

The TDRSS DAS provides near continuous downlink coverage for downloading GRB alert telemetry for delivery to the GCN and for alerting the ground of spacecraft emergencies. Alert Telemetry, in standard state-of-health format, is autonomously sent to alert the ground of critical alarm events such as safe hold or low bus/battery voltage. Real-time housekeeping data can also be transmitted ~~using a TDRSS link~~ for spacecraft and instrument monitoring and contingency support.

The MOC will routinely schedule approximately four to five ~~five to six~~ TDRSS~~ground station~~ passes per day to downlink the real-time and recorded~~science~~ data~~ via X-band~~, and to uplink commands.~~ and downlink real-time housekeeping via S-band. These passes will consist of a combination of ground station sites.~~ The scheduling of SN contacts is dependent upon the attitude of the observatory due to the position of the Ku-band antenna. The MOC will use the science timelines to determine the availability and duration of future SN contacts. Autonomous repointing of the observatory as well as ToOs may interrupt planned SN contacts. These interruptions are compensated by scheduling additional contact time with the SN.

The telemetry will undergo Level-0 processing when it arrives at the MOC; the MOC will subsequently transfer the Level-0 data to the GSSC for archiving, and to the IOCs for Level-1 processing. The MOC will also monitor the spacecraft and instrument housekeeping data for anomalies. The IOCs will use the Level-1 data for their own scientific investigations, and will transfer them to the GSSC for dissemination to the general scientific community. After the first year of scientific operation (during which the data will be accessible only to the instrument teams and a small number of GIs) the data should be available for analysis by the scientific community within two days after the observations. The IOCs and the GSSC will produce higher level data products such as a Point Source Catalog and gamma-ray burst catalogs, which will also be available through the GSSC. After the mission, the HEASARC will maintain a permanent archive of the GLAST data, response functions, analysis software and documentation. The transfer of data between ground system components and the processing of data within these components will be highly automated.

3.4.1 Mission Planning and Scheduling

The MOC and GSSC perform mission planning and scheduling during the regular 5-day operations shift. Scheduling several days in advance is expected to accommodate planning for weekends and holidays. Key planning information begins with a science target schedule and regular spacecraft activities, and includes target occultation, accommodation of operational exclusion zones, passage through the South Atlantic Anomaly (SAA), and available TDRSS resources~~Malindi or USN ground station passes~~. The planned four to five daily TDRSS contacts are expected to be only five to seven minutes in duration. This amount of contact time is sufficient to downlink the daily science and housekeeping data. Longer S-band only contacts may be scheduled (with the SN or ground stations) if additional contact time is necessary for commanding purposes such as the uplink of large instrument or spacecraft flight software.

The Science Support Center will plan the GLAST observations. During first year following on-orbit commissioning, the observatory will operate primarily in Sky Survey Mode. In Sky Survey Mode the spacecraft +Z axis is kept zenith pointing. Sky survey mode may also include a spacecraft rocking motion offset from the Z-axis to increase the effectiveness of the sky survey. The GSSC will monitor the sky coverage and may request modifications to the spacecraft motion to achieve optimal scientific return. During subsequent years guest observers will propose observations. Specific targets may also include secondary targets to be observed during earth occultation of a primary target. The GSSC works with the project scientist, LIOC, and GIOC to schedule science activities. The GSSC will have planning tools to evaluate the operational plan for earth occultation and other factors. The project scientist may request the GSSC evaluate a potential ToO with these tools. The GSSC will plan observing programs to optimize the science observing return and respond to GRBs detected by the instruments.

The GSSC will typically coordinate routine operations weeks in advance. Targets of opportunity (ToO) are requests from the project scientist (or his/her designee) to reposition the observatory for a phenomenon of interest, such as an Active Galactic Nucleus flare.

The IOCs will plan instrument loads and any special instrument activities. Special LAT activities could include disabling the onboard background rejection software for a short period of time, or special calibration targets. Special instrument activities that interrupt normal operations should be infrequent. The IOC requested instrument activities will be submitted to the GSSC, which will evaluate their impact on the science timeline; if the impact is acceptable, the GSSC will pass the request on to the MOC with scheduling instructions. These special activities would be incorporated into the timelines by the GSSC. For activities marked urgent by the IOC they will be passed directly to the FOT for uplink during an upcoming support.

The MOC will generate the integrated observatory timeline based on the science timeline, ground station, and TDRSS contact schedules, orbit products, and any engineering activities. This planning results in generation of time-tagged command loads for uplink to the spacecraft.

~~Malindi ground station contact scheduling is based on predetermined criteria (minimum length of pass, number of passes per day, maximum time between passes, etc.) and an updated orbit vector. The Malindi ground station provides the pass schedules to the MOC. The scheduling procedures for use of Malindi will be documented in the MOC to Malindi ICD. The scheduling of the Universal Space Network ground stations will be done in a similar way and will be documented in the MOC to Commercial Ground Station ICD. Emergency or unplanned supports will be coordinated with the appropriate ground station via voice and data links.~~

The SWSI is the MOC interface for scheduling the SN Ku-band return link, S-band return and forward link, and DAS services.~~both DAS and FWD services scheduling and real-time monitoring.~~ The SWSI will also be used by the MOC to ~~schedule near continuous 24-hour TDRS DAS support,~~ monitor TDRSS schedule changes, receive~~provide~~ alert information, and receive~~provide~~ service status data. TDRSS hand-over schedules are obtained from SWSI for use in mission planning and subsequent uplink to the spacecraft for antenna selection. ~~The SWSI will also allow the FOT to schedule TDRSS MA forward supports using the WSC Transmission Control Protocol (TCP)/Internet Protocol (IP) Data Interface Service Capability (WDISC).~~ The FOT will~~shall~~ provide GLAST spacecraft orbit vectors to the SN using SWSI.

A ToO will be executed less than six hours after the Project Scientist approves the ToO. If a ToO order from the GSSC arrives at the MOC outside of the regular 5 days-per-week operations shift, an on-call FOT engineer will be paged to come to the MOC to create and uplink the commands implementing the ToO.

3.4.1.1 Flight Dynamics Support

During the Launch and Early orbit period the Flight Dynamics Facility at GSFC will provide orbit and attitude determination support to the MOC. This will include validation of the onboard GPS orbit solution and the On Board Computer attitude solution.

GLAST mission planning and scheduling activities require time-tagged orbital event lists based on propagated GLAST orbits. GLAST orbit determination will primarily use the onboard GPS provided vector and ground software to generate the orbital event products. The orbital products and state vectors can then be forwarded from the MOC to the ground stations, the SN, the GSSC, and IOCs.

In the event of total on-board GPS failure the ground team may use one of several methods to propagate the GLAST orbits. NASA/GSFC continually receives the latest North American Air Defense Command (NORAD) "satellite catalog" of up-to-date satellite state vectors. The MOC would then propagate the state vectors to generate the necessary orbital products. A second method of generating orbital event products would utilize the GSFC Flight Dynamics Facility and differenced one-way Doppler data from two TDRS satellites. Once updated orbit information is available from FDF the MOC could generate the necessary orbital products. In addition the MOC would also need to uplink predicted ephemeris vectors to GLAST to maintain the spacecraft position knowledge.

3.4.2 Commanding

The GLAST spacecraft is~~may be~~ nominally commanded via ~~a 2 kbps S-band uplink provided by the Malindi and/or commercial USN ground stations. GLAST may also be commanded via a~~ the 250 bps MA or 4 kbps SA forward link service provided by TDRSS. The ~~Malindi~~ ground stations are used for contingency commanding support.~~ is primarily used for normal operations support with the commercial ground station providing backup capability as needed.~~ Quick response commanding is scheduled through TDRSS, e.g., to support~~ for contingency and L&EO operations, and for~~ ToO commanding.

The MOC utilizes Spacecraft Test and Operations Language (STOL) procedures to control GLAST command activities during ground station and TDRSS contacts. These procedures provide a set of command operations, which are prepared and verified pre-launch and maintained under configuration control. The use of STOL procedures enables automation of routine operations during off-shift periods. The Project command and telemetry database is maintained at the MOC. The database identifies critical commands, which could pose a potential danger to the spacecraft or the instruments. Protection is provided to prevent unintentional use of these critical commands.

Three types of spacecraft commanding are used for the GLAST spacecraft.

- Real-time commands
- Stored Command Processor (SCP) Absolute Time Sequence (ATS) table loads
- SCP Relative Time Sequence (RTS) table loads

Real-time commands are uplinked from the MOC for immediate execution during spacecraft ground station or TDRSS contacts. During L&EO operations, real-time commanding can consist of nearly any spacecraft activity. During normal operations, real-time commands will primarily consist of ATS and RTS table loading, SSR redumping activities, flight software loading, instrument table loading, and unplanned instrument activities. GLAST uses the Consultative Committee for Space Data Systems (CCSDS) Command Operation Procedure - Version 1 (COP-1) protocol to verify receipt of real-time commands during a ground station contact. The actual execution of~~For TDRSS contacts, receipt of~~ real-time commands is confirmed by end-item telemetry verification. The MOC maintains an electronic log of real-time commands that have been sent and verified.

For other than real-time commanding, the spacecraft utilizes SCP ATS table loads. These ATS loads contain time-tagged sequences of commands and are used for the majority of commanded functions on-board the spacecraft. These functions can consist of nearly any spacecraft activity, but will primarily consist of ground station contact sequences, instrument observation sequences and configuration, and various health and safety operations. The ATS loads are uplinked when the MOC is staffed and consist of at least 96 hours of time-tagged commands. The MOC verifies all ATS command loads against operational constraints prior to uplink. Successful uplink of an ATS command load is confirmed by a checksum operation on the entire contents of the ATS load.

For commonly used command sequences, the spacecraft utilizes SCP RTS table loads. There are 64 RTS tables that are allocated for use by fault management and routine operations. These RTS loads contain relative time-tagged sequences of commands. The spacecraft flight software, real-time command, or ATS command can execute or start RTS loads. The RTS loads are uplinked on an as needed basis via real-time command when the MOC is staffed.

3.4.3 Spacecraft & Instrument Monitoring

The MOC is responsible for spacecraft and instrument health and safety monitoring, as well as the verification of nominal mission execution and system status. The MOC monitors received SOH telemetry for out-of-limit situations, and proper spacecraft and/or instrument configuration. STOL procedures or scripts with ancillary software tools allow automation of telemetry monitoring to not only support off-shift periods, but to optimize MOC staffing during the regular 5-day shifts. This allows a small FOT to perform mission planning and scheduling as well as spacecraft and instrument monitoring, and other duties such as ToO support. Automated telemetry processing includes packet extraction, engineering unit conversion, limit checking with alarms, display, and rules verification.

After processing the telemetry from a ~~GN~~ pass, the MOC transfers the resulting Level-0 data to the appropriate IOC. The IOC analyzes the housekeeping data for out-of-limit conditions, abnormal instrument function, or signs of instrument degradation. In addition, anomalies indicating improper instrument performance are noted while the science data undergo Level-1 processing. The trends of various engineering parameters are monitored to assess the health of the instrument. If necessary, the IOC responds to anomalous instrument performance to preserve the instrument and maintain the integrity of the scientific data.

The MOC responds to many out-of-limit situations automatically. During off-shift periods, paging is used to notify on-call and backup FOT and GSSC personnel of situations requiring operator intervention. The on-call and backup operators have remote access to review system data or burst messages and quick-look analysis. If warranted, they are within close proximity allowing travel to the MOC for performing additional analysis or command operations.

3.4.4 Burst Alert Handling

Burst Alert messages are generated by the two instruments to quickly notify the science community of a significant GRB. Upon reaching predefined (and settable) threshold levels, the LAT and/or the GBM instruments will ‘trigger’ on a particular GRB. If the GBM detects a GRB, it will send an “Immediate Trigger Signal” (ITS) telecommand to the LAT and an “Immediate Summary Information” (ISI) telemetry packet to the ground. The GBM instrument has a much wider “field of view” than the LAT and will periodically update the LAT by sending “Calculated Information” (CI) telecommands to the LAT.

Lastly (for each burst), GBM will send a “Candidate Re-point Recommendation” (CRR) telecommand to the LAT within the first four minutes of the detected burst. The LAT will evaluate the CRR and decide whether to issue an Auto-Repoint Request (ARR) telecommand to the spacecraft. For bursts detected by the LAT, the LAT will send a “Trigger Record” (TR) to the GBM via telecommand and to the ground via telemetry packet. For a pre-defined time the LAT will continue to send “Update Record” (UR) telemetry packets to the ground. After a predetermined time or data characteristic the LAT will determine that the burst is over and send a “Closeout” telecommand to the GBM and “Closeout“ telemetry packet to the ground.

In the event that the GBM and LAT both detect the burst, the GBM will scale back (delay) its output to allow the LAT data priority on the downlink. The MOC will immediately forward ISIs and TRs to the GCN for distribution to the science community.

When CIs are received by the MOC they will be forwarded to specialized "burst alert processing" (BAP) software and the GIOC. The BAP will improve the data quality and forward this improved data to the GCN. The GIOC increases the data quality yet further and forwards these improvements to the GCN as well.

3.4.5 Targets of Opportunity (ToO)

The Target of Opportunity (ToO) observation will result from a ground-commanded repointing of the spacecraft that will interrupt previously scheduled observations and may inhibit Auto-Repoints from occurring for the duration of the ToO. The ToO observations allow near real-time observations to be initiated by the Project Scientist to respond to a transient astrophysical phenomenon.

3.4.5.1 ToO Observation Criteria

ToO observations are declared by the GLAST Project Scientist (or his/her designee) based on guidelines established by the Science Working Group. The Project Scientist may be requested to declare a ToO either because the criteria in a successful guest investigator proposal have been met or as a result of an astrophysical event. The request may reach either the Project Scientist directly or through the GLAST Science Support Center (GSSC). The Project Scientist will consult with the GSSC to determine the feasibility and the impact of the requested ToO on the current operational plan. The GSSC will evaluate the request using the GSSC's planning tools and operational expertise. After these consultations, the Project Scientist may decide to declare a ToO.

3.4.5.2 ToO Process Flow

Once the Project scientist has approved the ToO, the GSSC will generate the necessary ToO order, which it will then transmit to the MOC. ~~There will be a pre-determined weekly average number of ToOs that will be accepted by the Flight Operations Team (FOT) during off shift work hours.~~ The ToO order will include the coordinates of the source, the observation duration, instrument modes, interruptible status and any other information necessary to execute the ToO observation~~The ToO order will include the coordinates of the source, the observation duration, instrument modes and any other information necessary to execute the ToO observation~~.

The MOC will receive the ToO order from the GSSC and acknowledge its receipt. Upon receipt of the ToO order, the MOC will notify the FOT. During the off-shift hours the FOT will be on-call to provide the necessary ToO support.

The FOT will evaluate whether a new SN contact is required or whether an existing ~~Ground Network (GN)~~ contact can be used. The FOT will then proceed to generate the commands and perform conflict resolution with the existing spacecraft operations.

During the real-time contact the FOT will execute the ToO order. The observatory will then slew to the requested coordinates to observe the particular phenomenon. Upon successful uplink of the order the FOT will notify the GSSC. After completing the ToO the observatory will return to its nominally scheduled activities.

3.4.6 South Atlantic Anomaly Region

The GN&C subsystem will monitor the location of the spacecraft with respect to the South Atlantic Anomaly (SAA) region. The onboard stored data containing the location of the region can be updated on-orbit as necessary. Upon entry into the region the instruments will be notified so that appropriate safing actions can be taken to protect the observatory. It is anticipated that the LAT and GBM will stand down operations and take measures during the SAA in order to extend the life of their photo-multiplier tubes (PMTs).

3.4.7 Weekly Activities

MOC activities will primarily be set up on a weekly schedule. Due to single shift operations, most FOT activities occur during typical business hours. Nominal generation of command loads will occur ~~TBD~~ once per week. Mission planning activities (see Section 3.4.1, Mission Planning & Scheduling) produce command loads of a length determined by valid propagation times. Occasional revision to schedules may be necessary based on the GRB detections.

3.4.8 Level-0 (L0) Data and Delivery

The MOC shall receive all CCSDS-compliant telemetry frames from the spacecraft via the SN and GN links.~~Malindi ground station, commercial ground station, and the TDRSS DAS link~~. The L0 processing system will perform processing on all mission telemetry, and maintain the mission archive within the MOC. Functions performed include extraction of packets from frames, Reed-Solomon (RS) decoding, time ordering of data, removal of duplicate packets, and production data products with associated quality and accounting information.

The MOC manages the receipt, recording, processing to L0, and archiving of raw and L0 GLAST telemetry. This includes managing the on-board spacecraft recorder and scheduling of ground contacts. If the data quality is not satisfactory, the MOC will request a retransmission of the data to ensure the best available L0 product. Daily spacecraft data volume is approximately 36 Gbits (TBR). The L0 data, which is the final, time-ordered, duplicate-removed data sets of GLAST telemetry, is archived and delivered to the LIOC, GIOC, and GSSC for further processing. The MOC also maintains an archive of the raw telemetry and relevant ancillary data to support any required processing of these data sets.

The MOC is required to provide ~~at least~~greater than 98 ~~(TBR)~~ percent of received telemetry in the form of L0 data sets. A log of data received, processed, distributed and quality control information is maintained. The total ETE mission data loss is expected to be less than 2% ~~(TBR)~~.

3.4.9 Data Archival

The MOC archives the raw telemetry files for the life of the mission. The last seven days are also available on-line. The MOC archive is designed primarily to support operations, including off-line analysis, trending, and anomaly resolution. The MOC also maintains a 30-day on-line archive of housekeeping telemetry, command transmissions, and MOC processing statistics and status.

The GSSC will archive the Level-0 data it will receive from the MOC; the GSSC does not expect to distribute this data except in an emergency. After the first year of science operations the GSSC will make available online the Level-1 data it will receive from the IOCs. Access to the online databases at the GSSC ~~(and the ASI mirror site)~~ will be the primary method of distributing these data to the general scientific community. The format of the GSSC's databases will be compatible with the HEASARC. The GSSC's computer system will be a subset of the HEASARC's, and during the mission the GSSC will transfer the data to the HEASARC. The HEASARC will maintain these data, as well as the analysis software and documentation, as GLAST's permanent archives after the mission is over.

3.4.10 Anomaly Response

Out-of-limit conditions detected in GLAST telemetry or other ground segment operations generate alarms for the FOT, as appropriate. During off-shift hours, on-call personnel are paged and review remote displays to determine if operator intervention is required. If warranted, personnel will travel to the MOC to resolve the condition or further analyze the anomaly. Sustaining engineering personnel will be contacted as appropriate. Remote engineering stations aid in the speedy analysis and resolution of any anomalies. During normal operations (post-L&EO checkout), the chain of responsibility for different levels of anomalies begins with the FOT for routine out-of-limits. If a spacecraft emergency is declared, the GLAST Project Scientist is notified and assumes responsibility (See Section 4.2.4.).

The GLAST observatory has significant auto-safe mode capabilities. The spacecraft automatically places itself and its instrument complement in safe hold mode should critical telemetry violations occur. In addition, each instrument will safe itself should certain conditions occur. Safe mode cannot be exited except by ground command. Standard procedures for the detection of, response to, and resolution of anomalies and exit from safe mode will be developed by Spectrum

Astro in conjunction with the FOT and instrument teams to address all known major failure modes.

A GLAST operational anomaly tracking system is implemented prior to the start of pre-launch simulations, and is used to track the status of all spacecraft, instrument and ground segment anomalies for the duration of the GLAST mission. The GLAST Operations Manager approves closeout of all anomaly reports.

3.4.11 Computer Security

Special attention is made to computer security in the development of the MOC and other ground facilities to prevent intrusion and potential disruption of operations. Computer security shall conform to NASA Procedures and Guidelines for Security of Information Technology NPG 2810.1. A formal plan will cover internal MOC systems, commercial lines for ground station communications, and connections to GSFC that includes the IONet. The separate IOCs and GSSC Local Area Networks (LANs) have their own firewalls and access monitoring functions.

3.5 GSSC DATA PROCESSING

The GSSC will receive all the Level-0 data from the MOC for archiving. The GSSC will receive Level-1 processed data from the IOCs. ~~The GSSC will be responsible for providing Level-1 data to the ASI Science Data Center (ASDC). Operationally, the ASDC and GSSC may receive data from the IOCs at the same time, from the same servers, and using the same data protocols. The ASDC will mirror these databases for use by Italian scientists.~~ The GSSC will have backup Level-1 processing pipelines that mirror the production pipelines at the IOCs; the GSSC's backup pipelines will be activated in an emergency with the concurrence and assistance of the instrument teams.

The GSSC will also undertake certain Level-2 processing of LAT data to keep the astronomical community informed of the progress and results of the mission, and to assist GIs in planning GLAST-related research. Such processing may include maps of counts and exposure for the entire sky and for selected regions (e.g., the Galactic center or the region about 3C273). The GSSC will also monitor selected sources of general astrophysical interest. The Level-2 data will be available on the GSSC website and upon request.

During all phases of the mission the GSSC will be the primary source of data for the GIs and the general astronomical community. After the observations necessary for a guest investigation have been performed, the investigator will create Flexible Image Transport System (FITS) files of the counts from the desired observations extracted from the counts database (see the discussion below). The investigator will then transfer the FITS files back to his/her computer; the analysis software will be available through the GSSC's website.

Finally, the GSSC is responsible for producing and maintaining databases of the data products it will receive from the IOCs or it will produce itself. ~~The ASDC will mirror selected databases using the data products the GSSC will provide.~~ These GSSC databases will be used during the mission and will become the archives afterwards. They will be constructed to conform to the standards of the HEASARC and will be created and maintained within the HEASARC.

A GLAST Project Data Management Plan describing the data and data products will be available from the GLAST Project. The instrument teams provide simulated data to assist in pre-launch verification of the GSSC system. Extensive use of the expertise of the GLAST Science Team is utilized in developing the GSSC pipeline processing system.

3.6 GSSC COMMUNITY SUPPORT

The GSSC will support the general science community in analyzing GLAST data by providing analysis software and assistance in using this software. The instrument teams are responsible for managing the development of the analysis software, but the GSSC is collaborating in defining the necessary suite of analysis tools and is providing resources for the development. Most of the tools will be "FTOOLS" developed in the HEASARC's HEADas system; a user-friendly interface will be provided. Users will download the GLAST analysis tools from the GSSC's website, although some tools, such as the tools to extract data from the GSSC' databases, will run on the GSSC's servers.

The tools will be accompanied by copious documentation on the GSSC website explaining how the tools are used, describing their range of applicability, and presenting their underlying methodology. Sample analysis sessions will be provided. The GSSC will run an online help desk; a "Frequently-Asked Questions" section will be extracted from the help desk queries. The GSSC also plans to run workshops and demonstrations at conferences.

3.7 SUSTAINING ENGINEERING

Sustaining engineering functions for the ground segment, spacecraft bus, and instruments are designed to maintain an operational ETE system for the acquisition of science data for the duration of the science mission. Sustaining engineering activities are managed and coordinated by the MOC with support from the Spectrum Astro and instrument teams. Sustaining engineering for the GSSC, HEASARC, and International Data Centers are handled by their respective organizations.

3.7.1 Spacecraft Sustaining Engineering

Day-to-day spacecraft operations at the MOC includes the monitoring of real-time and playback spacecraft housekeeping telemetry (reference section 3.4.3) and the creation of an archive of housekeeping data. The MOC routinely generates selected plots and reports on the status of various spacecraft systems, and performs a weekly systems analysis per defined procedures.

Either Spectrum Astro or the Goddard Flight Software Maintenance branch will provide routine sustaining engineering support to the FOT for the duration of the mission. Remote access to the engineering telemetry will allow engineers to review spacecraft status and trend data from the MOC data archive. Sustaining Engineering support would include, for example, expert spacecraft systems engineering analysis, solar array degradation over time, battery performance characterization, and thermal degradation. The sustaining engineering contractor submits periodic spacecraft system status reports to the MOC based on review of received housekeeping data and is also on-call to support anomaly resolution activities, as required.

Either Spectrum Astro or the Goddard Flight Software Maintenance branch will maintain the flight software for the spacecraft. Any changes to the flight software are validated by the sustaining engineers prior to providing the load to the FOT. The GLAST Configuration Control Board (CCB) will ensure that all changes are proper and that earlier versions of the software are available if anomalies are identified in subsequent versions. A flight software test bed may be used to validate planned updates to the spacecraft flight software.

3.7.2 Instrument Sustaining Engineering

Day-to-day instrument operations at the MOC includes the monitoring of real-time and playback instrument housekeeping telemetry (reference section 3.4.3) and the creation of an archive of housekeeping data. The MOC routinely generates selected plots and reports on the status of various instrument systems, and performs a weekly systems analysis per defined procedures. Analysis of the housekeeping data in the MOC tracks instrument performance as the mission progresses and helps detect any subsystem problems.

The instrument teams provide sustaining engineering support for the GLAST instrument complement. Remote access to the MOC archive data allows the instrument teams to review housekeeping data, and perform trending of selected subsystem parameters. Sustaining engineering and calibration activities are clearly defined pre-launch, and executed and supported on a routine basis by the instrument teams. A periodic report on instrument system status is provided to the MOC, and appropriate information provided to the GSSC to support data analysis of GLAST data by the science community. Instrument teams and software personnel are also on-call for anomaly resolution support.

Instrument flight software will be maintained by the instrument teams, who will perform configuration control and validate changes to the software loads. Once the loads are validated, they are transferred to the MOC for uplink. The MOC will validate correct instrument destination, check for critical commands, and verify correct uplink of the loads to the spacecraft.

3.7.3 Ground Segment Sustaining Engineering

Sustaining engineering activities for the MOC include periodic upgrade and testing of the MOC hardware and software systems. Data quality and systems monitoring aid in the identification and resolution of hardware degradation. Maintenance contracts are in place with MOC Commercial Off-the-Shelf (COTS) vendors to cover bug fixes, consulting support, and software upgrades for the life of the mission.

The MOC will be responsible for maintaining the configuration of the MOC hardware, software, documentation, display pages, Project Database (PDB), STOL PROCs, as well as any other items requiring control. The GLAST CCB will approve changes prior to implementation. The MOC will validate and test certain updates prior to implementation.

Sustaining engineering functions for the ground network and RF ground stations are the responsibility of the contracted service providers. A sustaining engineering plan will be obtained from each service provider to ensure acceptable practices are in place.

4.0 OPERATIONS ORGANIZATION & MANAGEMENT

The GLAST mission combines the capabilities and strengths of NASA/GSFC, university and industry partners. GLAST has a multi-national science team with representatives from the United States, France, Germany, Italy, Japan, and Sweden. Jonathan Ormes of NASA/GSFC is the Project Scientist.

4.1 GLAST PROJECT ORGANIZATION

The instrument Principal Investigators (PIs) for LAT and GBM are Peter Michelson and Charles Meegan, respectively. The Project Scientist, Jonathon Ormes, has overall responsibility and authority for the mission. The decision-making process flows from the Project Scientist's delegation of the mission technical management to the Project Manager (PM). Day-to-day project management authority is vested in the PM who oversees the efforts of four major mission segments: 1) Spacecraft Contractor, 2) Instruments, 3) I&T, and 4) Ground Systems.

The Ground System/Operations Manager, Michael Rackley, is responsible for the delivery of the ground system. The GLAST MOC and Flight Operations Team are provided by Goldbelt Orca/Omitron, Inc. of Greenbelt, Maryland under the direction of Doug Spiegel, Ground Segment Manager.

4.2 GLAST MISSION OPERATIONS TEAM

The GLAST mission operations team is a function of mission phase.

4.2.1 Pre-Launch Operations

During the Pre-Launch Operations phase, the mission operations team will include members from NASA/GSFC, Spectrum Astro, the instrument teams, Goldbelt Orca/Omitron, and the Universal Space Network~~, and ASI~~.

NASA/GSFC is responsible for providing the physical MOC facility. Science operations systems to support instrument and science operations are provided by the LIOC, GIOC, and GSSC. Goldbelt Orca/Omitron is responsible for providing the flight operations systems and FOT personnel to support observatory operations and to assist in operating, coordinating, and troubleshooting the ground system. The FOT is responsible for obtaining a thorough knowledge of the spacecraft, instrument, and ground system designs, operations, and associated products.

Spectrum Astro is responsible for delivering the spacecraft on-orbit to NASA (within a L+60 day time-frame), and has the lead role in ensuring launch and mission readiness of spacecraft and associated operations. Spectrum Astro is responsible for providing the FOT ~~(Omitron)~~ with opportunities to become familiar with the spacecraft design and associated operations products, via methods such as training, participation in the product review process and spacecraft testing.

The instrument teams are responsible for ensuring the activation and mission readiness of their instruments, including associated operational products. The instrument teams will be responsible for providing the FOT with opportunities to become familiar with the instrument design, operations, and associated products, via methods such as training, participation in the product review process and instrument testing.

~~ASI and USN are responsible for ensuring the mission readiness of their ground station, including associated operational products. Each is responsible for providing the FOT with opportunities to become familiar with ground station, operations, and associated products, via methods such as interface testing and simulations. ASI and USN will provide an RF suitcase that will simulate and verify compatibility with the Malindi and USN ground stations.~~

4.2.2 Launch and 60-Day Checkout Operations

Spectrum Astro leads the conduct of Launch and Early Orbit (nominal 60-day) checkout operations from the NASA/GSFC MOC. Spectrum Astro will provide the L&EO Director who will lead operations activities as identified in the "Operations Agreement: GLAST Mission Operations Roles and Responsibilities". This document delineates the roles and responsibilities of the various organizations involved in preparing for and conducting launch, early orbit, and normal operations support for the GLAST observatory. The L&EO Director will have the authority to give direction to the supporting element personnel as needed to ensure that overall operations support is provided. The FOT provides support in MOC operations and maintenance, and utilizes this phase to enhance FOT training and readiness for normal operations.

A launch script incorporating spacecraft, instrument and ground system activities will be developed using inputs from all segments. NASA personnel will take a lead role in putting together the complete launch script. Spectrum Astro is responsible for providing and approving all information related to activation and checkout of the spacecraft interfaces to the instruments. The IOCs are responsible for providing and approving all information related to activation and checkout of the instruments.

4.2.3 Normal Operations

At the completion of the checkout of the spacecraft and interfaces with the instruments and ground system, a Project-level review is held. If successful, operational responsibility is handed over to the FOT, under direction of the NASA Mission Director. Overall responsibility and authority at the MOC is held by the Mission Director. The FOT, provided by Goldbelt Orca/Omitron, is led by the

Operations Manager, who has responsibility for spacecraft operations, spacecraft and instrument state-of-health, ground station- and TDRSS-associated activities, and overall mission planning and command upload generation.

The FOT consists of ~~Omitron~~ operations engineers who oversee and support routine operations tasks and perform critical tasks such as contingency analysis. During MOC staffed shifts one of the operations engineers is designated as Flight Ops Lead. Off-shift duty operators are designated on a rotating basis, and selected from available operations engineers. On-call duty engineers respond to pages for off-shift critical anomalies. Flight Ops Leads generate weekly operational status reports for the Operations Manager, who in turn reports to the Mission Director. Operations Manager approval is required for all MOC configuration changes, software changes, and procedure revisions. The Operations Manager is the management interface to external organizations supporting MOC operations (such as the commercial ground station service provider). The Operations Manager is also the technical interface to the instrument teams, sustaining engineers and the GSSC.

Support is provided by sustaining engineering teams and off-site instrument teams who perform periodic system status analysis from workstations at their own facilities. Space is provided in the MOC facility for additional personnel as required for special operations. Status summaries are periodically provided to the Operations Manager. The sustaining engineers and instrument teams also provide anomaly resolution support when called upon by the Operations Manager. Management issues are resolved through the Mission Director.

4.2.4 Contingency Operations

Routine out-of-limits and non-critical anomalies are dealt with by the FOT, as appropriate. Persistent or repeating anomalies result in the notification of the Mission Director and appropriate members of the spacecraft and instrument teams. Anomalies unresponsive to standard procedures will result in notification of the Mission Director, who will be responsible for their resolution and, if necessary, for declaration of a spacecraft emergency. If an instrument emergency is declared, the responsibility for resolution transfers to the GLAST instrument PI, who may call a “tiger team” to develop a solution or alternative operating mode.

~~4.3 GLAST SCIENCE TEAM~~

~~The GLAST Science Team is headed by Jonathan Ormes (NASA/GSFC). The large and diverse international collaboration has representation from the United States, France, Germany, Italy, Japan, and Sweden.~~

~~4.4 WORKING GROUPS~~

~~The Science Working Group (SWG) has the responsibility to make sure the GLAST mission is optimally designed to carry out its mission within the important constraints both programmatic (cost, schedule) and technical (mass, power, etc.).~~

~~The SWG will:~~

~~1.Assist the GLAST Project in establishing overall requirements and priorities in support of the mission plan.~~

~~2.Assist the GLAST Project in maintaining, updating, and prioritizing the science requirements.~~

~~3.Assist the GLAST Project in the definition and development of the calibration, data handling, data reduction, and mission operations systems.~~

~~4.Participate in GLAST Project reviews and meetings to coordinate scientific requirements and to assist the GLAST Project in mission decisions as they relate to scientific objectives.~~